

Economic Benefits of Earth Science Information used in Decision- Making to Reduce Wildfire Loss

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Economic Basics

- Information is an input to decision-making
 - The value of information is measured as increased expected net benefits from a management action
 - Costs averted = benefits
- Examples:
 - Use of surface imaging in choice of tillage practices increases farm productivity and reduces erosion
 - Atmospheric information for timing year and season increases probability of post-fire restoration success
- Information is used in decisions that would reduce wildfire costs – for management during wildfire suppression and prior to wildfire occurrence

Objectives of This Talk: Importance of Decision-Making Framework

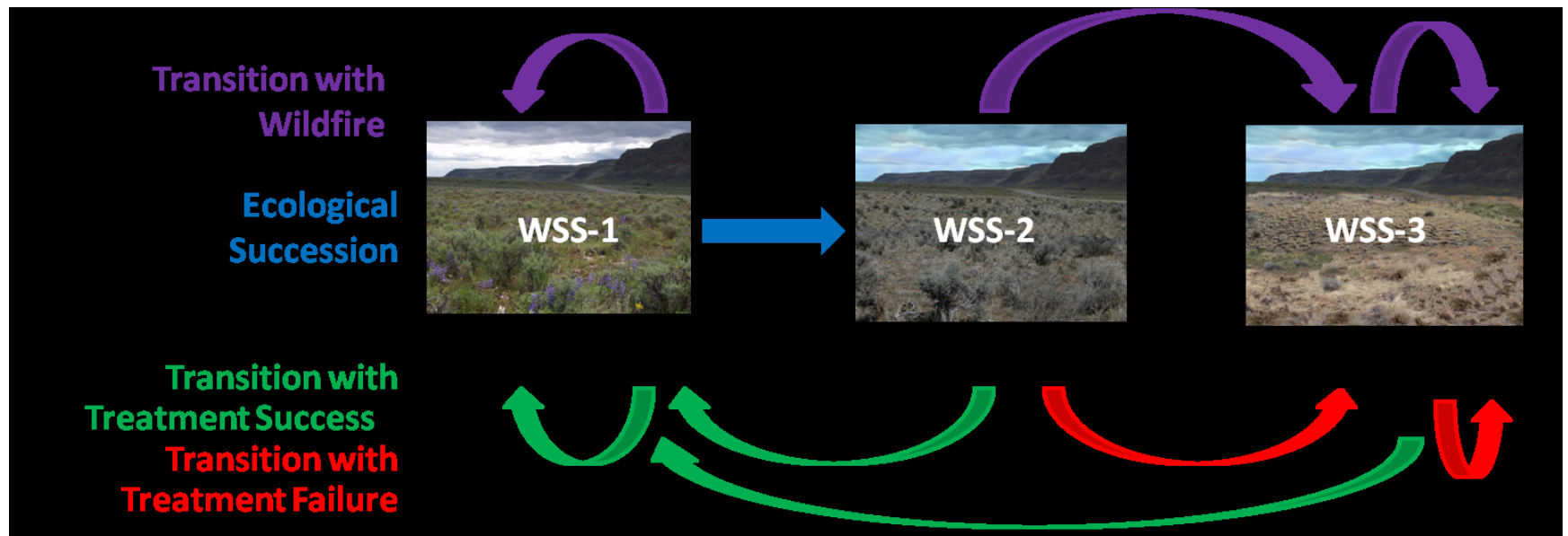
- Information as an input is available for use by first investing in and improving upon decision-making frameworks/models.
 - Several fire behavior models in use today rely on specialized earth information
- The cost of the initial investment to develop models is spread over the total sum of gains from its use to avert costs.
- This talk will focus on 2 integrated economic/ecological/spatial models that use earth information for pre-fire decisions that would
 - reduce the probability that an ignition would result in a severe fire,
 - and if ignition occurred, would reduce the costs of suppressing the fire and also the cost of damages
- In this talk, we will walk through the 2 examples that show complexity of how information influences decision-making.
 - **The value of the information and the models used are highly related.**

2 Pre-Fire Decision Examples

- Fuel treatments that would reduce the severity of Fire and improve post-fire restoration of degraded ecosystems
 - Requires models and information re the dynamics of ecosystems, and fuel accumulation over time to plan timing and spatial patterns of treatments
- Design of policies for strategic targeting private lands for defensible space investments
 - Requires models and landscape information at a spatial scale that includes private and public lands.

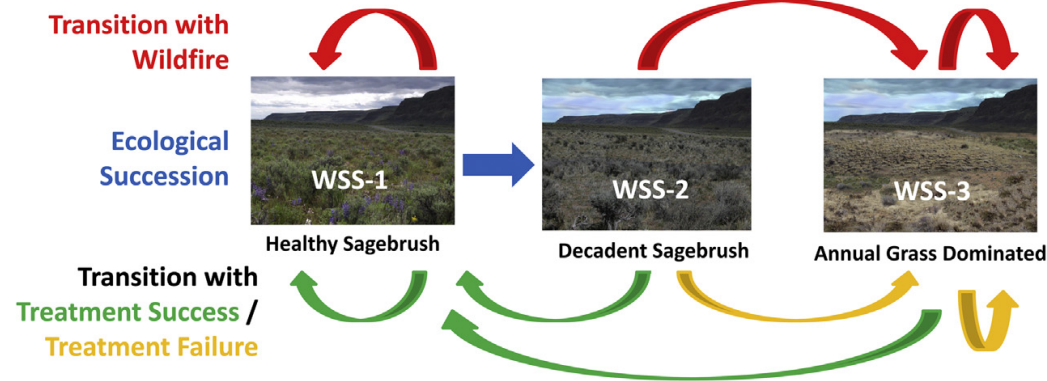
Example 1: Ecological Models and Information and Efficient Fuels Treatment Strategies

A Stylized State and Transition Ecological Model for Western Rangelands



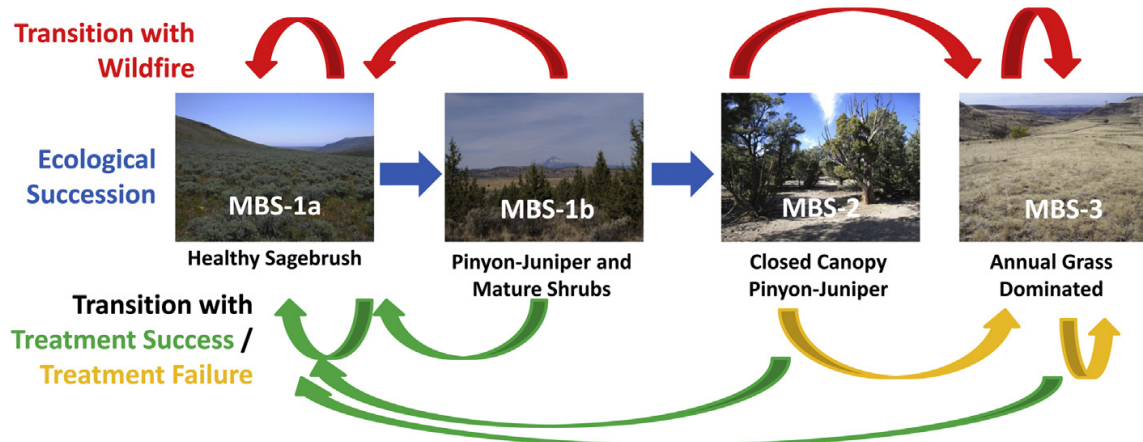
Develop and parameterize for applicable ecological models

a



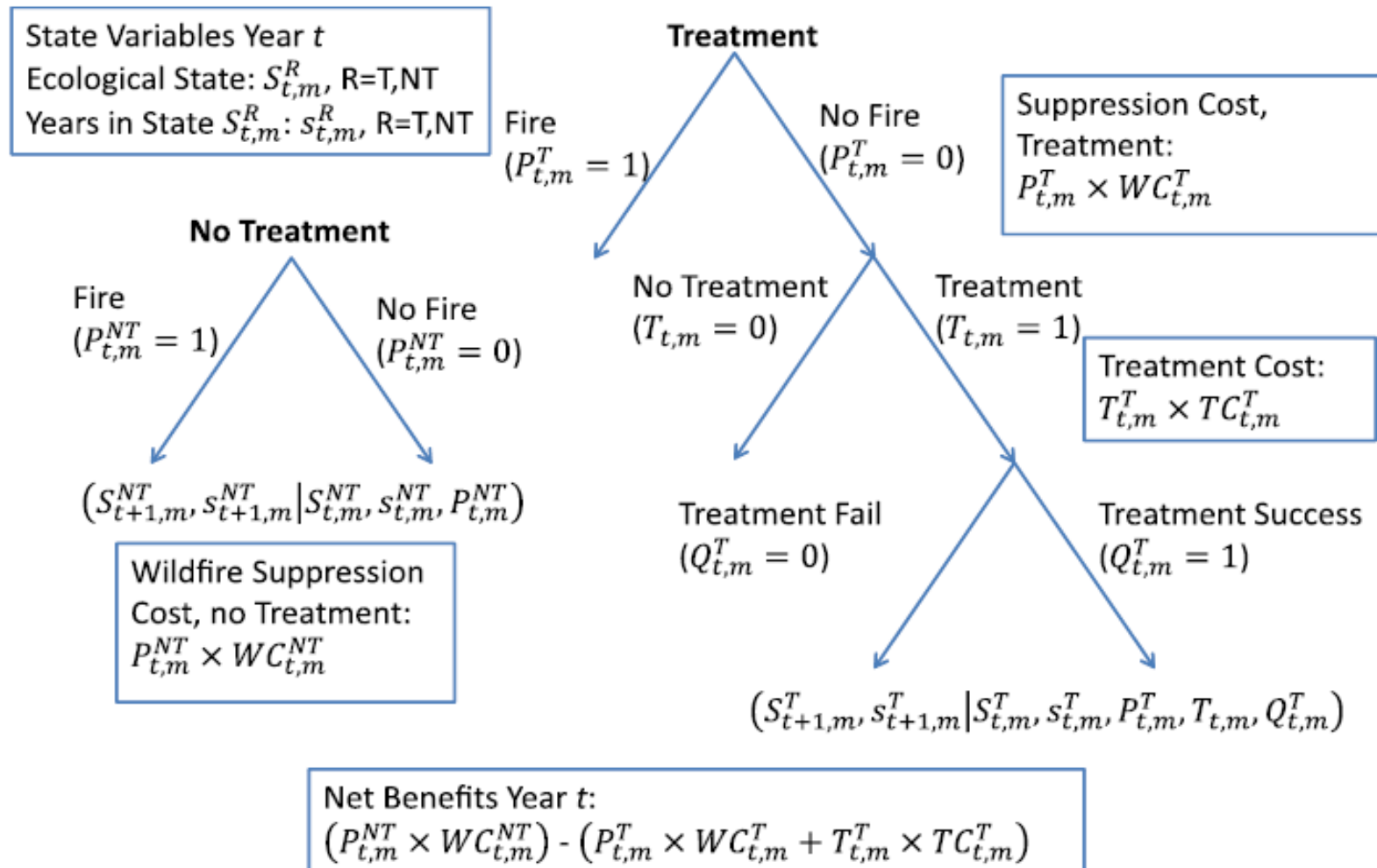
Wyoming Sagebrush System - WSS

b



Mountain Big Sagebrush System - MBS

Decisions: timing and outcomes



Fuel and Restoration Treatments: Present Valued Net Benefits

$$\text{NPV}_m = \sum_{t=1}^{200} \frac{1}{(1+r)^t} \left(P_{t,m}^{\text{NT}} \text{WC}_{t,m}^{\text{NT}} \right) - \sum_{t=1}^{200} \frac{1}{(1+r)^t} \left(P_{t,m}^T \text{WC}_{t,m}^T + T_{t,m}^T \text{TC}_{t,m}^T \right)$$

Expected values calculated from simulation with stochastic parameters run 10,000 times:

$$E[\text{NPV}] = \sum_{m=1}^{10,000} \text{NPV}_m.$$

Wyoming Sagebrush System

Wyoming sagebrush steppe results (\$ per acre; 2010 dollars).

	Initial ecological state		
	WSS-1	WSS-2	WSS-3
	Shrubs and perennial grasses	Decadent sagebrush with annual grasses	Invasive annual grass dominated
Mean number of wildfires – no treatment	15.1 (0, 26) ^a	15.2 (0, 27)	22.2 (15, 30)
Mean number of wildfires – with treatment	1.8 (0, 4)	12.1 (0, 28)	6.4 (1, 17)
Mean total suppression costs (NPV) – no treatment	\$349.8 (\$0, \$1141.1)	\$364.2 (\$0, \$1218.6)	\$389.8 (\$149.6, \$703.0)
Mean total suppression costs (NPV) – with treatment	\$56.0 (\$0, \$250.5)	\$231.4 (\$0, \$658.9)	\$250.7 (\$2.8, \$607.6)
Mean wildfire suppression costs savings (NPV)	\$293.8 (\$0.0, \$1043.8)	\$132.8 (–\$430.7, \$934.1)	\$139.1 (\$0.6, \$418.5)
Mean number of treatments	3.1 (2, 4)	2.0 (1, 4)	41.8 (5, 121)
Mean number of successful treatments	3.1 (2, 4)	1.5 (0, 4)	2.5 (1, 4)
Mean treatment costs (NPV)	\$22.1 (\$19.7, \$23.5)	\$204.4 (\$205.4, \$209.3)	\$252.69 (\$469.5, \$4974.9)
Final state – no treatment ^b (WSS-1, WSS-2, WSS-3)	0, 734, 9266	0, 731, 9269	0, 0, 10000
Final state – with treatment (WSS-1, WSS-2, WSS-3)	10,000, 0, 0	4949, 0, 5051	9885, 0, 115
Mean wildfire suppression costs savings net of treatment costs (NPV)	\$271.7 (–\$23.5, \$1021.6)	–\$71.6 (–\$636.1, \$727.8)	–\$2782.5 (–\$4965.1, –\$107.5)
Mean benefit–cost ratio (NPV)	13.3	0.7	0.06

^a 5th and 95th percentiles.

^b 'Final State' is the final state of the system (WSS-1, WSS-2, or WSS-3) after 200 years.

Sensitivity Analysis for Uncertainty of Ecological Parameters

Table 6

Impacts of shorter fire return intervals in WSS-2 on benefits and costs. Bold numbers signify that these numbers refer to the fire return intervals in WSS-2 listed in the top row.

	Fire return interval in WSS-2 (years)				
	75	50	25	15	5
Initial state – WSS-1					
Mean total suppression costs (NPV) – no treatment	\$349.80	\$463.90	\$662.00	\$798.20	\$1013.00
Mean total suppression costs (NPV) – with treatment	\$56.00	\$59.10	\$57.30	\$57.70	\$59.20
Mean treatment costs (NPV)	\$22.10	\$22.09	\$22.09	\$22.08	\$22.08
Mean wildfire suppression costs savings net of treatment costs (NPV)	\$271.70	\$382.70	\$582.50	\$718.50	\$931.70
Mean benefit–cost ratio (NPV)	13.3	18.3	27.4	33.5	43.2
Initial State – WSS-2					
Mean total suppression costs (NPV) – no treatment	\$364.20	\$480.50	\$686.50	\$832.30	\$1051.40
Mean total suppression costs (NPV) – with treatment	\$231.40	\$232.90	\$258.80	\$278.00	\$415.00
Mean treatment costs (NPV)	\$204.40	\$202.92	\$198.16	\$193.36	\$164.69
Mean wildfire suppression costs savings net of treatment costs (NPV)	–\$71.60	\$44.60	\$229.50	\$360.90	\$471.70
Mean benefit–cost ratio (NPV)	0.7	1.2	2.2	2.9	3.9

Simulations with alternative fire-return intervals
Treatments on initial states 1 and 2 for WSS

Sensitivity Analysis for Uncertainty About Thresholds

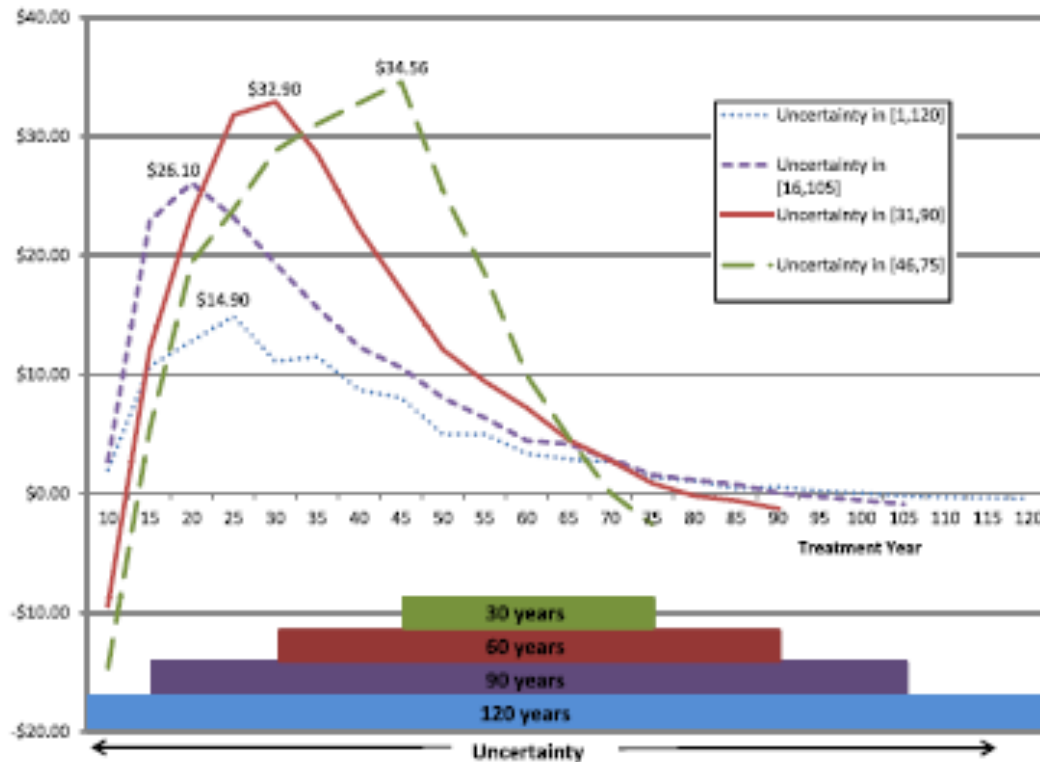
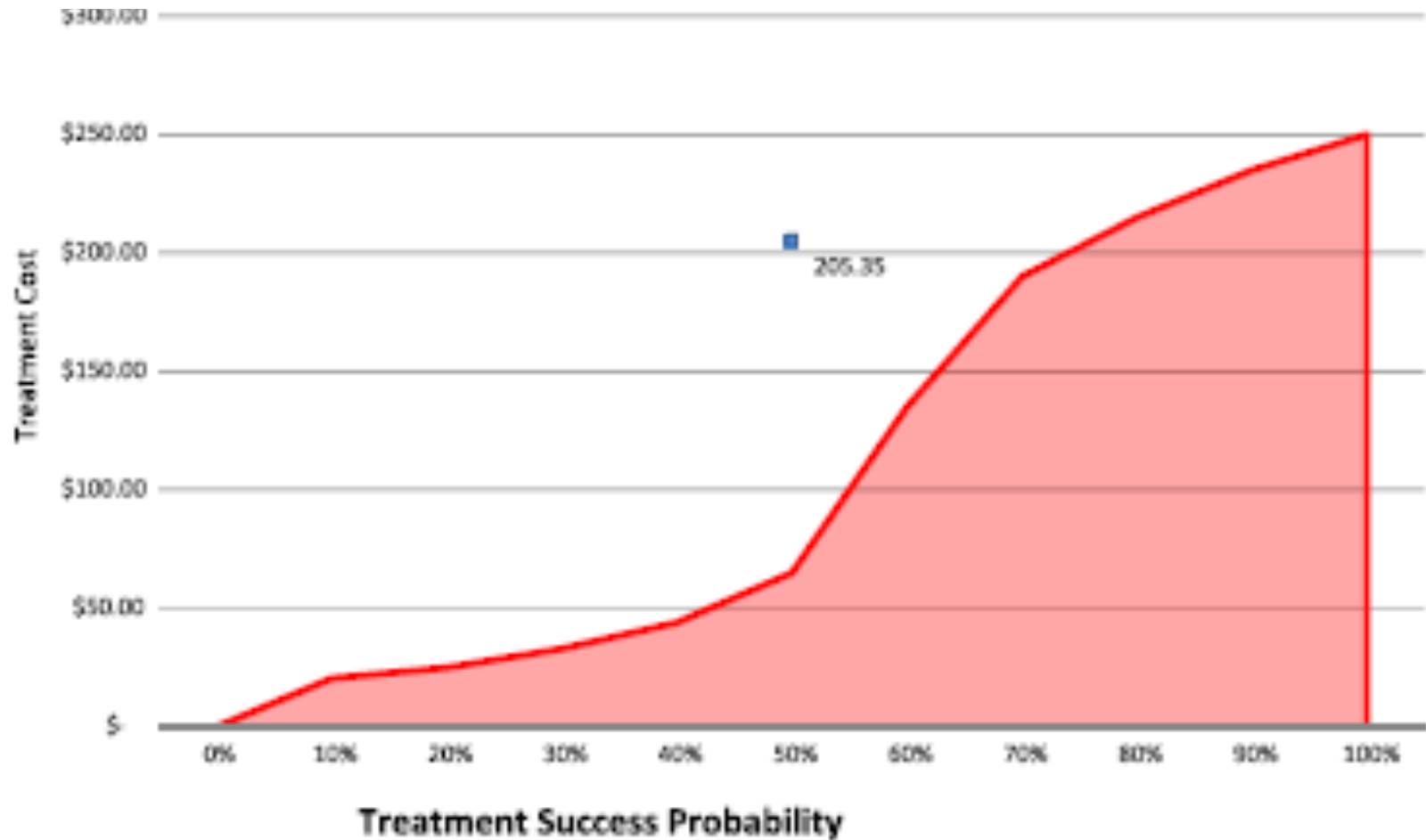


Fig. 5. Expected net benefits from treatment under an uncertain threshold between WSS-1 and WSS-2.

Sensitivity Analysis for Probability of Treatment Success



Summary:

- Economic problem and definition of relevant units of change
- Optimize net returns from fixed set of resources to achieve stated goals
- Analytical Framework
 - Measure differences between constructed/simulated “with” and “without” scenarios
 - Quantify dollar-values associated with changes
- Biophysical changes and relationships include
 - Time frames and dynamics: with and without scenarios
 - Probabilistic events: stochastic effects (ignition, precip, drought)
 - **Management changes odds of outcomes**
 - Irreversibility: species loss, ecological thresholds
- Expected Present Value of Net Benefits

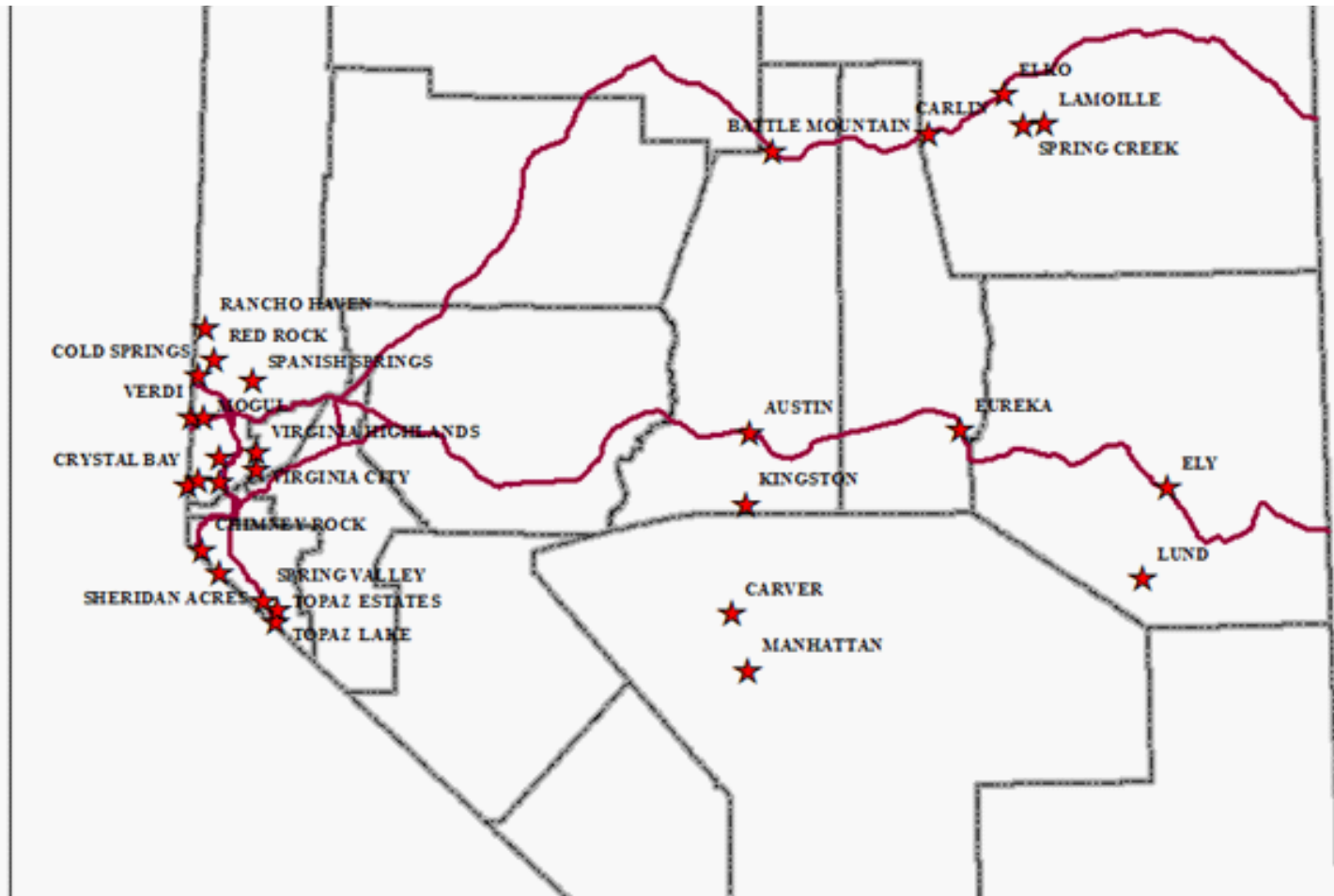
Example 2

- Hypotheses: are private DF investment decisions influenced by: neighbors' decisions, landscape type, fuel accumulation, physical aspects (slope, precip, wind speed, etc), fire fighting infrastructure?
 - patterns of clusters of private decisions are mutually influential
 - Landscape and atmospheric information condition private and public decisions, as they affect expected outcomes of investments
 - Could design policy to exploit these relationships to induce greater levels of private investment in defensible space
- Policy contribution 1: if so, then policies to target specific private investments in DF can trigger further private investment without additional incentives
- Policy contribution 2: if patterns of adjacent public lands treatments influence private decisions – choose location and timing to take advantage, when possible

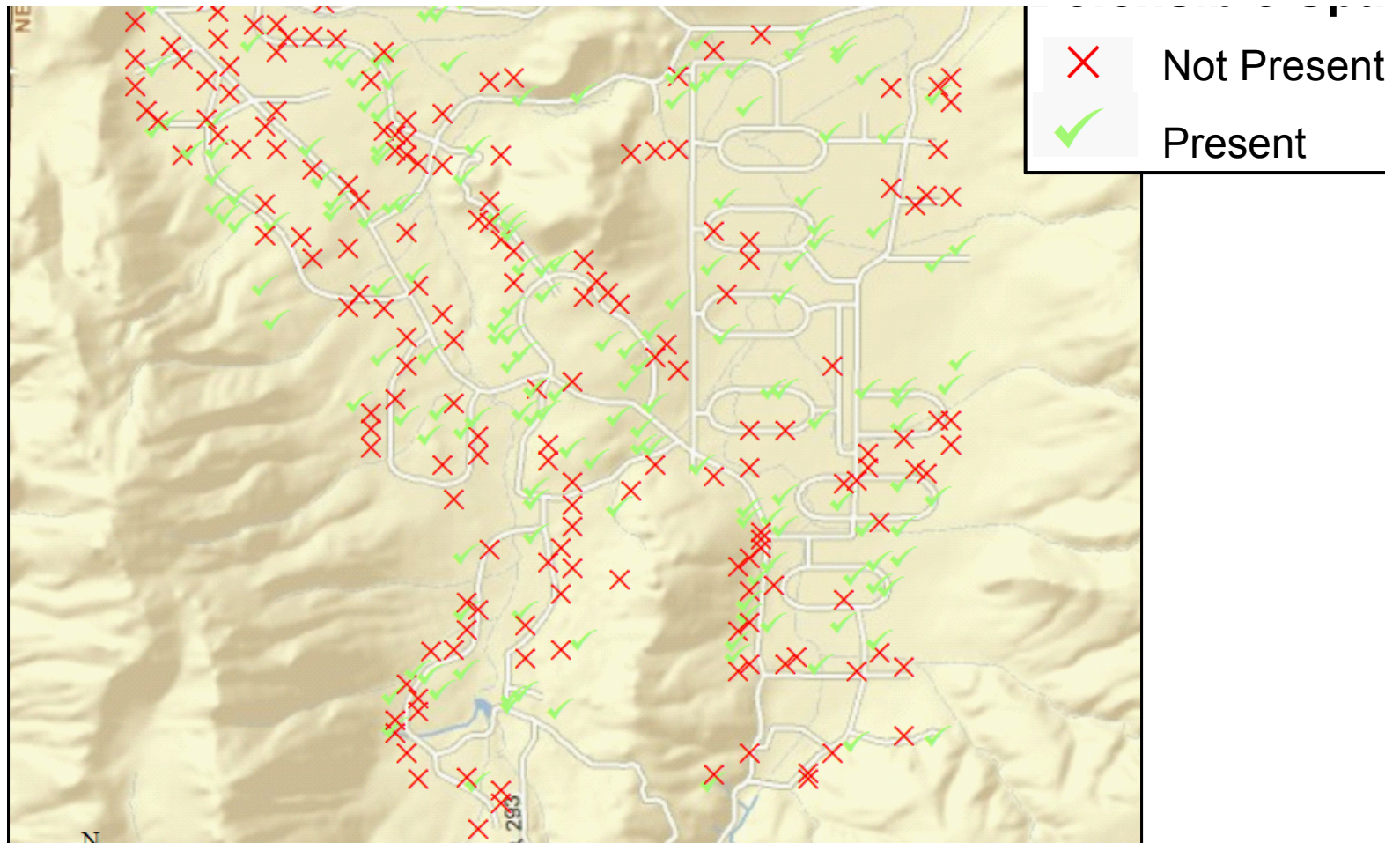
Study of 35 WUI communities and adjacent public lands Included 4 types of landscapes



Locations of the 35 Communities



Example of defensible space patterns in a community



Patterns – measured via spatial parameters (morán's index)

- Few DF properties within many without
 - Hypotheses:
 - Incentive to invest is to “protect from neighbors”
 - Investing in DF is not seen as effective, where effective is influenced by measureable factors
- Many DF properties and a scattered few without
 - Hypotheses:
 - Others' investments allow the few to “free-ride”
 - DF is effective, with level of effectiveness influenced by measureable factors

Data used for spatial estimation model

- Property characteristics
 - Minimum 30 feet defensible space, home value, acreage, HOA, distance to nearest large fire in last 6 years
- Wildland fire policy variables
 - Width of primary road, # resources within 10 miles and per capita, # treatments on public lands within 10 miles in last 5 years and last 10 years.
- Biophysical variables
 - Community fuel load, landscape type, ave daily wind speed, aspect, slope, elevation relative to ave in community, ave # lightening strikes within 10 miles

Results

- Fire Protection Resources
 - Negative and significant in PJ woodlands and sub-alpine samples (not signif in rangeland, grassland)
 - 50% reduction in numbers of resources in sub-alpine forest communities more than doubles predicted # homes with DF
- Interpretation
 - Homeowners perceive more resources near residence reduces risk of loss
- Reverse Causation
 - Investment in resources because low private DF levels

Results

- Hazardous Fuel Reduction Treatments
 - Positive and significant in PJ woodlands and sub-alpine communities (not in rangeland and grassland)
- Average fuel loads locally
 - However, higher average loads reduce homeowner investment in DF
- Interpretation
 - Homeowners believe hazards on adjacent public lands can be high enough that investing in private DF is futile

Results

- Biophysical determinants of wildfire risk
 - Predominant vegetation type, Slope, elevation differential, wind speed, Fuel loading are all significant in affecting DF decisions
 - Homeowners in rangeland, PJ woodland and grassland communities more likely to invest in DF than are those in forested communities
 - Explanation: crown fire risk difficult to reduce on own property alone, high costs of DF (include loss of amenity values)

Results

- Strategic Complements
 - $\hat{\rho}$ is positive and significant in full sample (0.6529), sagebrush rangeland (0.6595), pinyon-juniper woodlands (0.4151), and alpine forest (0.5807) subsamples but is not significantly different from zero in grassland subsample.
- Interpretation
 - The efficacy of defensible space at reducing wildfire risk is increasing in the level of neighbors' defensible space and this effect dominates the reduction in baseline wildfire risk and the increased loss of visual seclusion.
- Risk Externalities v. Post-fire Home Values
 - Variation in $\hat{\rho}$ across communities with different predominant vegetation is evidence in support of the risk externalities explanation.

Implications

- Externalities
 - Homeowners underinvesting in defensible space due to risk externalities in sagebrush rangeland, pinyon-juniper woodland, and alpine forest communities but not in grassland communities.
 - Defensible space investments are strategic complements.
 - Potential for tipping policies to improve well-being in these communities.
- Interaction with Other Wildland Fire Policies
 - Hazardous fuel reduction treatments likely promote private investment in defensible space in pinyon-juniper woodlands and alpine forest communities.
- Homeowner Knowledge
 - Homeowners are aware of the potential for defensible space to reduce their wildfire risk.

Implications

- Tipping Policies

- Tipping policies provide financial incentives or other inducements to encourage homeowners to invest in defensible space with the hope that the additional homes with defensible space will generate further homeowner investment through strategic complementarities.

- Analysis

- Use estimated model to predict the number of additional homeowners that invest in defensible space as a result of a tipping policies that target 10, 25, 40, and 60 initial homes.
- 1,000 randomly-drawn alternative configurations of new homes with defensible space.

Prediction of # of new homes with DF with a Tipping Policy

Additional Homes with Defensible Space in New Community Equilibrium											
	n	% Def. Space	# Def. Space	10 New Homes		25 New Homes		40 New Homes		60 New Homes	
				Avg.	Max	Avg.	Max	Avg.	Max	Avg.	Max
Sagebrush Communities											
Averages:	265.53	47%	123.94	12.05	22.59	24.49	37.20	34.79	48.15	39.37	51.17
Yields:				1.21	2.26	0.98	1.49	0.87	1.20	0.66	0.85
Pinyon-Juniper Communities											
Averages:	199.00	42%	77.33	3.12	9.83	5.73	14.40	14.15	26.67	28.87	45.00
Yields:				0.31	0.98	0.23	0.58	0.35	0.67	0.48	0.75
Alpine Forest Communities											
Averages:	289.10	16%	55.30	5.22	12.90	12.24	24.20	18.98	31.60	26.81	39.90
Yields:				0.52	1.29	0.49	0.97	0.47	0.79	0.45	0.67
Grassland Communities											
Averages:	120.00	39%	47.50	0.20	4.50	-0.99	6.50	-3.29	4.50	-6.46	0.00
Yields:				0.02	0.45	-0.04	0.26	-0.08	0.11	-0.11	0.00
All Communities: Totals											
Averages:	252.54	37%	91.97	7.89	16.60	16.14	27.66	24.21	36.82	31.67	44.12
Yields:				0.79	1.66	0.65	1.11	0.61	0.92	0.53	0.74

Thank You!

- Questions ...

